Exhibit 5

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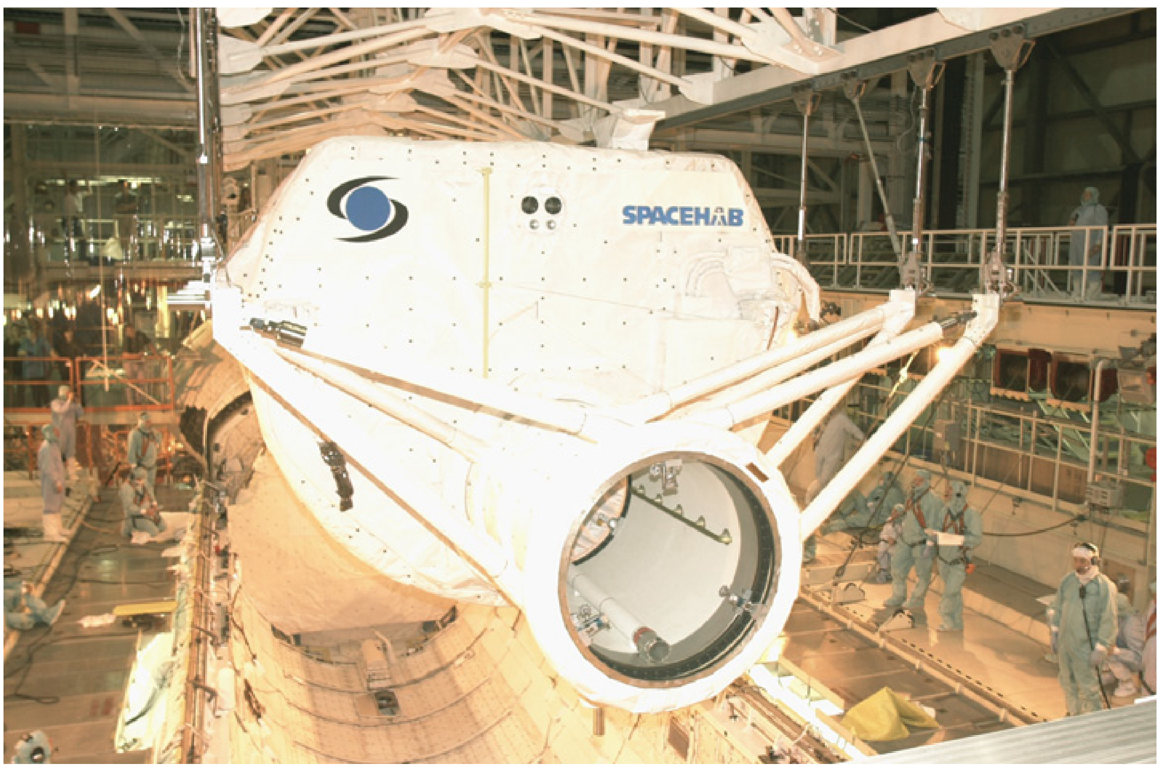
Payloads

SPACEHAB Research Double Module (RDM)

SPACEHAB Inc.'s Research Double Module (RDM) is making its first flight on STS-107. The RDM is a pressurized aluminum habitat that is carried in the space shuttle's cargo bay to expand working space aboard the shuttle. The RDM is connected to the shuttle middeck by a pressurized access tunnel. Boeing-Huntsville performed the RDM's systems integration for SPACEHAB and serves as the company's mission integration contractor. SPACEHAB Single Modules outfitted for research or logistics and Double Modules outfitted for logistics have flown on 15 space shuttle missions to date.



The SPACEHAB Research Double Module (RDM) and pressurized access tunnel are lowered toward Columbia's payload bay.

National Aeronautics and
Space Administration

Studying Fires in Orbit

Combustion Module–2 (CM–2)

Light a candle and it quickly forms the familiar teardrop shape caused by hot, spent air rising and cold, fresh air flowing in behind it to keep the fire going. But this airflow also obscures many of the fundamental processes that we need to understand if we are to fine tune the many ways we control combustion in manufacturing, transportation, heating, fire safety and pollution.

Conducting combustion experiments in the microgravity environment of orbit eliminates gravitational effects and slows many combustion processes so they become easier to study. Almost everything about fires changes in microgravity, and many differences are counter-intuitive:

- Microgravity fires may spread faster upwind than downwind, opposite to the behavior seen on Earth,
- While fire in space is often weaker than on Earth, flames in microgravity can be sustained under more extreme conditions than flames on Earth, and
- Turbulent flames, thought to be completely independent of gravitational influence, have doubled in size in microgravity conditions.

Professor Gerard Faeth at the University of Michigan has said that these findings show that gravity has impeded the rational development of combustion science much as the atmosphere has impeded astronomy.

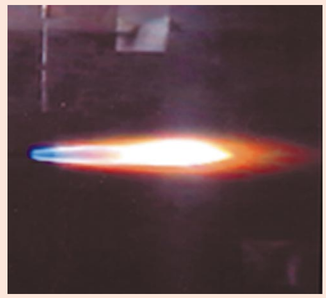
To build on what we have learned from space about combustion, the STS–107 mission will refly the Combustion Module that flew on the Microgravity Sciences Laboratory 1 and 1R (STS–83 and –94) in 1997. Upgraded and designated CM–2, the module will accommodate three experiments, Laminar Soot Processes (LSP–2), Structure of Flame Balls at Low Lewis-number (SOFBALL–2), and Water Mist Fire Suppression Experiment (Mist).

LSP–2 and SOFBALL–2 are reflights from the Microgravity Sciences Laboratory 1; Mist is a new experiment. They are detailed in separate fact sheets.

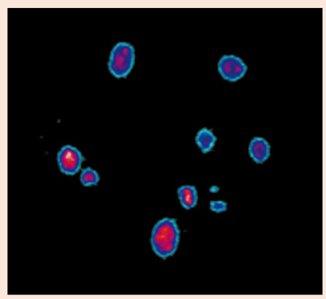
CM–2 will complete the primary science plan for these investigations, and help set the stage for expanded, long-term experiments aboard the *International Space Station* with the Fluids and Combustion Facility that will be installed in Destiny, the U.S. lab module.

Project Manager: Ann Over, NASA Glenn Research Center, Cleveland, OH
Deputy Project Manager: David Frate, NASA Glenn Research Center, Cleveland, OH
CM-2 Science Contact: Dr. David Urban, NASA Glenn Research Center, Cleveland, OH

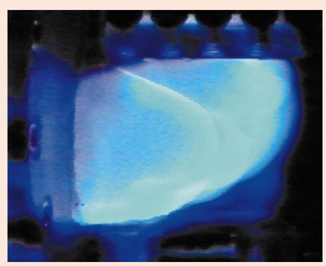
CM–2 Experiments



Laminar Soot Processes (LSP): Evaluate and predict flame shape and internal structures; determine the nature of the soot emission process; validate new universal equations for soot and temperature in a flame; and investigate the soot-bursting hypothesis. Results will improve our understanding of turbulent flames found in many combustion devices on Earth.



Structures of Flame Balls At Low Lewis-Number (SOFBALL–2): Improve our understanding of the flame ball phenomenon and lean (low fuel) burning combustion; determine the conditions under which they can exist; test predictions of duration; and derive better data for critical model comparison. Results will lead to improvements in engine efficiency, reduced emissions, and fire safety.



Mist: Measure the effectiveness of fine water mists to extinguish a flame propagating inside a tube to gain a better understanding of the mist fire-suppression phenomenon. What is learned will help us design and build more effective mist fire-suppression systems for use on Earth, as well as in space.

Background Information

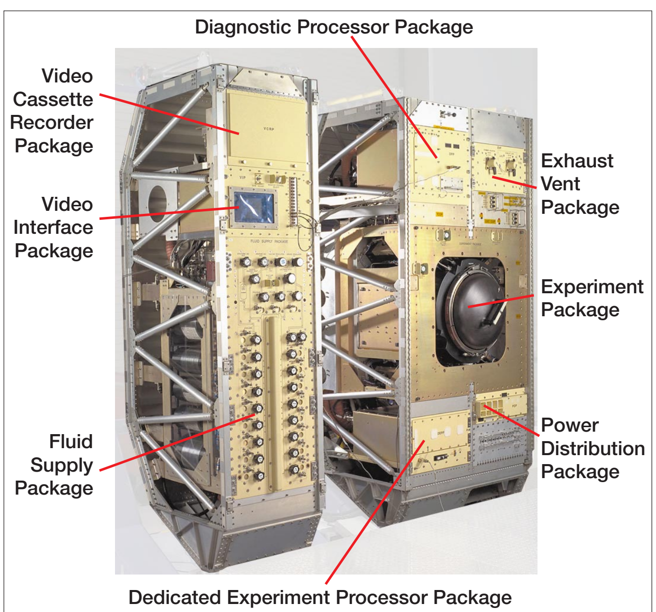
CM–2 Background

The Combustion Module (CM) is a state-of-the-art space laboratory to let a wide range of users perform combustion experiments in space. Until 1997, combustion experiments were developed for individual experiments. This was time-consuming and costly. NASA decided that a better and less expensive approach was a reusable, modular combustion facility that could accommodate diverse experiments with the same support hardware and unique Experiment Mounting Structures (EMS). This approach led to the CM.

CM–2 Design

Most CM–2 subsystems are in a double rack and a single rack standing side-by-side in the SPACEHAB module. Flight spares and EMS's are carried in a Maximum Envelope Stowage System that is the same size as a double rack. Central to the CM–2, in the double rack, is the Experiment Package, a 90-liter combustion chamber with six ports for three intensified near-infrared cameras, one color camera, and three black and white cameras; a gas chromatograph; crew switches; and thermistors. The Fluid Supply Package, in the single rack, is a complex gas control and distribution system containing 20 composite overwrapped compressed gas bottles.

The Videocassette Recorder Package consists of four Hi-8 video recorders. The Exhaust Vent Package includes a blower, canister, and other fluid components for cleanup and evacuation of chamber gases. The Dedicated Experiment Processor Package is the main processor for experiment command and control, and connects to the crew laptop (the CM–2 human interface). The Video Interface Package is the primary video interface for switching, routing, and display. The Diagnostic Processor Package is the video frame grabber and storage system for digital data. The Power Distribution Package controls and conditions the power from the Shuttle/SPACEHAB for all CM–2 packages. Finally, the EMS are experiment-unique chamber inserts. Each contains an ignition system and special sensors; the Mist EMS also contains test gases, a water mist generator, and a canister to remove water and carbon monoxide after each test.



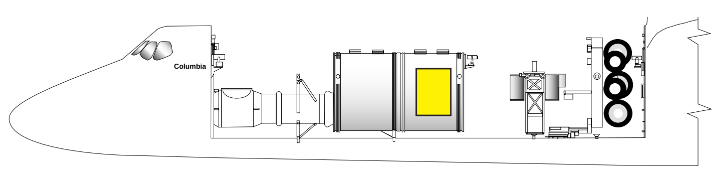
CM–2 Statistics

Size: Main racks — 2.13 m tall by 1.52 m wide by 0.91 m deep (7×5×3 ft)
Weight: Main racks — 835 kg (1840 lb); other CM–2 hardware — 161 kg (355 lb)
Subsystems: Eight rack-mounted components, three chamber inserts
Power Usage: Average — 419 W (dc);Peak — 543 W (dc)
Chamber Size: 40 cm (16 in.) dia. × 76 cm (30 in.) long; 91 liters (23.4 gal.) empty
Cameras: Seven — one color, three intensified near-infrared, three black and white
Lasers: Two sets of low-power beams for LSP and Mist measurements
Sensors: Dozens of pressure, temperature, and radiation sensors
Gas Analysis: Gas chromatograph determines percent of each kind of gas
Gas Bottle Sizes: 21 — three × 10 liters, nine × 3.8 liters, eight × 0.7 liters, one × 0.4 liters
Gas Bottle Usage: Fourteen SOFBALL mixes, two air, two LSP fuel, three gas chromatographs
Software: Three 25 MHz computers, ~35,000 lines of code
Video: Four VCRs, frame grabber, and two-channel downlink capability; 15.2 cm (6-in.) diagonal screen onboard
Data: 13.3 gigabytes storage (20 hard drives/flash memory cartridges)
Crew Time: 92 hours

Flight Operations

Although the flight crew is in the spotlight for shuttle missions, a team of engineers, scientists, and other support personnel on the ground will make it all possible. The CM–2 team, comprising almost 40 engineers and scientists, will work side-by-side with the NASA Johnson Space Center Mission Control team in Houston, TX. For STS–107, 16 days of around-the-clock operations are conducted to ensure safety and mission success. The CM–2 experiments timeline spans the entire mission.

The LSP experiment includes 15 burns lasting about five minutes each, with active participation by the crew to adjust test conditions during the burn. The 15 SOFBALL burns range from 25 to 167 minutes each, during which the Shuttle is placed in "free drift" with no attitude control so that the flame balls float freely inside the combustion chamber. The crew checks on the flame balls every ten minutes and adjusts camera gains as needed. The 36 Mist burns are each very short ranging from less than one second to several seconds in duration. Mist includes six tests run by the crew and 30 tests run by the ground team using commands sent directly to CM–2's on-board computer.



Approximate location of this payload aboard STS–107.

Photos. Page 1 from top: University of Michigan at Ann Arbor, University of Southern California, Colorado School of Mines; page 2, NASA.

FS-2002-06-070-MSFC

Tackling a Hot Paradox

Laminar Soot Processes–2 (LSP–2)

The last place you want to be in traffic is behind the bus or truck that is belching large clouds of soot onto your freshly washed car. Besides looking and smelling bad, soot is a health hazard. Particles range from big enough to see to microscopic and can accumulate in the lungs, potentially leading to debilitating or fatal lung diseases.

Soot is wasted energy, and therein lies an interesting paradox: Soot forms in a flame's hottest regions where you would expect complete combustion and no waste. Soot enhances the emissions of other pollutants (carbon monoxide and polyaromatic hydrocarbons, etc.) from flames and radiates unwanted heat to combustion chambers (a candle's yellowish glow is soot radiating heat), among other effects.

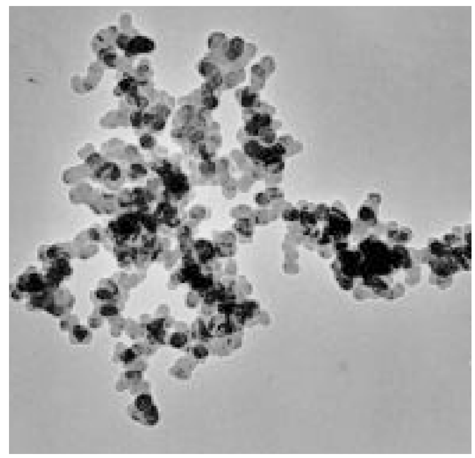
Soot belched by a diesel engine is more than ugly — it's dangerous. While the largest particles may wash out of the air when it rains, smaller particles linger and possibly endanger human health and the environment.

The mechanisms of soot formation are among the most important unresolved problems of combustion science because soot affects contemporary life in so many ways. Although we have used fire for centuries, many fundamental aspects of combustion remain elusive, in part because of limits imposed by the effects of gravity on Earth. Hot or warm air rises quickly and draws in fresh cold air behind it, thus giving flames the classical teardrop shape. Reactions occur in a very small zone, too fast for scientists to observe, in detail, what is happening inside the flame.

Principal Investigator: Prof. Gerard M. Faeth, The University of Michigan, Ann Arbor, MI
Project Scientist: Dr. David L. Urban, NASA Glenn Research Center, Cleveland, OH
Project Manager: Ann Over, NASA Glenn Research Center, Cleveland, OH

The Laminar Soot Processes (LSP–2) experiments aboard STS–107 will use the microgravity environment of space to eliminate buoyancy effects and thus slow the reactions inside a flame so they can be more readily studied. "Laminar" means a simple, smooth fuel jet burning in air, somewhat like a butane lighter. This classical flame approximates combustion in diesel engines, aircraft jet propulsion engines, and furnaces and other devices.

LSP–2 will expand on surprising results developed from its first two flights in 1997. The data suggest the existence of a universal relationship, the soot paradigm, that, if proven, will be used to model and control combustion systems on Earth. STS–107 experiments also will help set the stage for extended combustion experiments aboard the *International Space Station*.



Soot particles from MSL–1 experiments (top) are about 10 to 60 nm across and formed aggregates 1,000 nm (1 micron) wide. This is similar to soot formed in terrestrial sources.

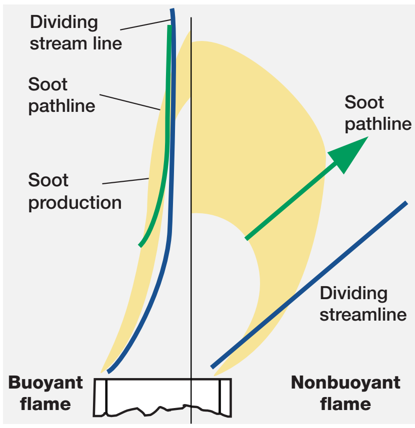
Applications

Fine-tune burner design and operation to:
- Control soot production in combustion processes,
- Reduce radiative heat transfer from soot particles that can damage engines
- Improve electric power generation efficiency by increasing radiative transfer from soot in flame to furnace walls while maintaining complete soot burnout (no emission),
- Enhance soot production in processes for carbon black used in tires and applications,
- Enhance computational combustion studies to design new systems that are optimized at the start, and retrofit existing systems.

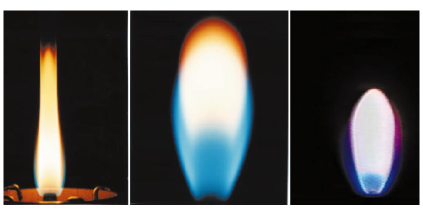
Background Information

Science

Microgravity provides an unprecedented opportunity to investigate soot processes relevant to practical flames. The chemical pathways that form soot are highly controversial in the science community. When the flame temperature falls below about 1300 °K (1900 °F), no soot is formed. Above that, hydrocarbon fuels pyrolyze or break down, even as most of the reactions form carbon dioxide and water vapor. These molecular fragments produce other molecules, including polycyclic aromatic hydrocarbons (PAH's) that coalesce into solid carbonaceous particles — soot — that are linked to human cancers in a number of studies.



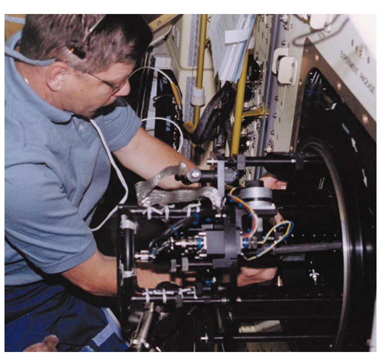
In buoyant flames (bottom left), soot mainly nucleates at the outer boundary of the soot production region, then moves inward before approaching the flame sheet once again near the flame tip. In nonbuoyant flames (bottom center and right), soot mainly nucleates near the inner boundary of the soot production region, and then is drawn directly toward the flame sheet.



The LSP investigation observes soot processes within laminar jet diffusion flames where a hydrocarbon jet burns in still air. Microgravity produces nonbuoyant laminar jet flames which allow observations of soot processes that cannot be duplicated on Earth. Normal gravity generates buoyant motion due to the large variations of gas densities in flames. These motions introduce soot particle motions that do not represent most practical flame environments where local effects of buoyancy are small.

Hardware

LSP–2 experiments will be conducted inside the Combustion Module (CM–2) facility flown in 1997 and modified for SPACEHAB. CM-2 will also host the Structure of Flame Balls at Low-Lewis number –2 (SOFBALL–2) and Water Mist experiments. CM–2 is detailed in a separate fact sheet. Diagnostic instruments for LSP include a color camera, a soot volume fraction system (using the dimming of a laser shining through the flame), and a soot temperature measurement system. An Experiment Mounting Structure provides a large volume to allow laminar flames to form on one of two burners with diameters of 0.4 mm (0.016 in.) and 0.8 mm (0.0315 in). They produce a flame 20 to 60 mm long (0.8 to 2.4 in). Soot samplers (for six test points) snap through the flame to capture particles for post-flight analysis.



Dr. Roger Crouch, a payload specialist on MSL–1, services the LSP experiment.

Affected Fields

Transportation: Internal combustion engines on aircraft (jet and piston), rail, ships, trucks, buses.
Industry: Power plants, process plants that use combustion heating.
Safety: Reduced loss of life and property due to improved understanding of building fires.

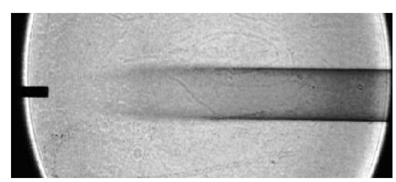
On-Orbit Operations

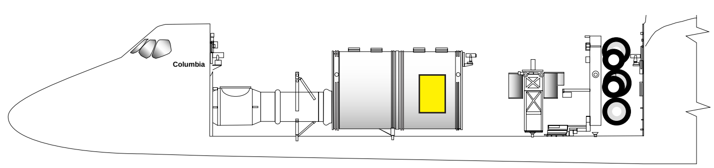
LSP–2 science operations will last almost 42 hours and cover 15 test points using ethylene or propane fuel in air. LSP–2 is operated by the flight crew through a laptop computer connected to the CM–2. Setting the smoke height will require guidance from the science team at Johnson Space Center.

Previous Results

On the Microgravity Sciences Lab–1 mission in 1997, LSP yielded several surprises. The LSP team discovered a new mechanism of flame extinction caused by radiation from soot. The mechanism is unusual because the flame quenches near its tip, unlike conventional extinction of buoyant flames where the flame quenches near its base. This phenomenon has significant implications for spacecraft fire safety and for selecting test conditions for future studies of nonbuoyant soot containing flames. The team also made the first observations of steady soot-containing nonbuoyant flames both with and without soot emissions. These provided textbook examples of soot formation processes in practical flames that are invaluable for developing methods for controlling the emissions of pollutant soot.

LSP uses a small jet burner, similar to a classroom butane lighter, that produces flames up to 60 mm (2.3 in) long. Measurements include color TV imagery (above), and laser shadowgraphs whose dimming indicates the quantity of soot produced in the flame (below).





Approximate location of this payload aboard STS–107.

Photos. NASA, University of Michigan at Ann Arbor.

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